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WHAT'S NEW IN INTENSIVE CARE

What is new in burn shock resuscitation?

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Burn injuries involving a significant total body surface area (TBSA) produce a negative interstitial pressure, concomitant tissue edema, and hypovolemia, collectively termed burn shock. Initial resuscitation is a critical intervention, typically initiated when TBSA involvement is ≥ 20%. Insufficient resuscitation leads to tissue hypoperfusion, burn wound progression, and excess mortality [1]. Conversely, over-resuscitation contributes to complications such as abdominal and extremity compartment syndromes, pulmonary edema, prolonged mechanical ventilation and excess mortality [2].

From resuscitation formulas to individualized fluid titration

Resuscitation formulas were developed to predict expected fluid requirements of the burn victim during the first 24 h post-injury. The Parkland formula remains the most widely used recommending 4 mL/kg/%TBSA of balanced crystalloids [3]. Despite this strategy, the patient often remains in a controlled hypovolemic state until 18–24 h post-injury signaled by an increase in lactate and renin [4]. However, many patients receive fluid volumes significantly in excess of Parkland and there is increasing concern that this may cause harm. The modified Brooke formula, which prescribes 2 mL/kg/%TBSA in the first 24 h, is an alternative approach endorsed by professional bodies and leads to an overall reduction in fluid administration when used as an initial rate although many patients still receive volumes in excess of their predicted requirement [5]. Due to significant variability in individual patient fluid volume requirements (influenced by mechanism of burn injury, presence of smoke inhalation, prehospital cardiac arrest, and escharotomy), fixed-volume resuscitation targets should only be used to establish the initial flow rate, before progressing to dynamic goal-directed fluid titration [6].

The initial aim of burn shock resuscitation is not to achieve euvolemia (as a degree of hypovolemia is expected and should be tolerated), but rather ensure adequate organ perfusion. Urine output remains the most common endpoint to assess resuscitation adequacy, targeting 0.5 mL/kg/hour (ideal body weight) [6]. Failure to meet this, or excess urine production, should prompt clinical reassessment and hourly adjustment of fluid delivery rates. It is important to note that using urine output as an indicator of adequate perfusion is not without problems. Multiple factors independent of fluid status can lead to oliguria in the burn-injured patient including cytokine response, rhabdomyolysis, and neurohormonal activation [7]. Raised intra-abdominal pressure (IAP) secondary to fluid overload can also reduce urine output, with further fluid administration worsening the scenario. Conversely, a rapid drop in plasma albumin concentration following capillary leak can lead to a misleading diuresis due to the drop in intravascular oncotic pressure, as can hyperosmolar states such as hyperglycemia or ethanol intoxication. In a young patient without pre-existing kidney disease, a low urine output is likely to be due to hypovolemia in the first hours following the burn injury. The persistence of oliguria despite restoration of adequate perfusion markers, a mean arterial pressure > 65 mmHg, and the absence of fluid responsiveness with an increasing central venous pressure (CVP) after fluid challenges should lead the clinician to reconsider further fluid resuscitation and look for cardiac dysfunction to avoid over-resuscitation and fluid overload. Additional markers, including serum lactate, hematocrit, and acid–base status, offer valuable adjunctive data pertaining to volume status and adequacy of organ perfusion,

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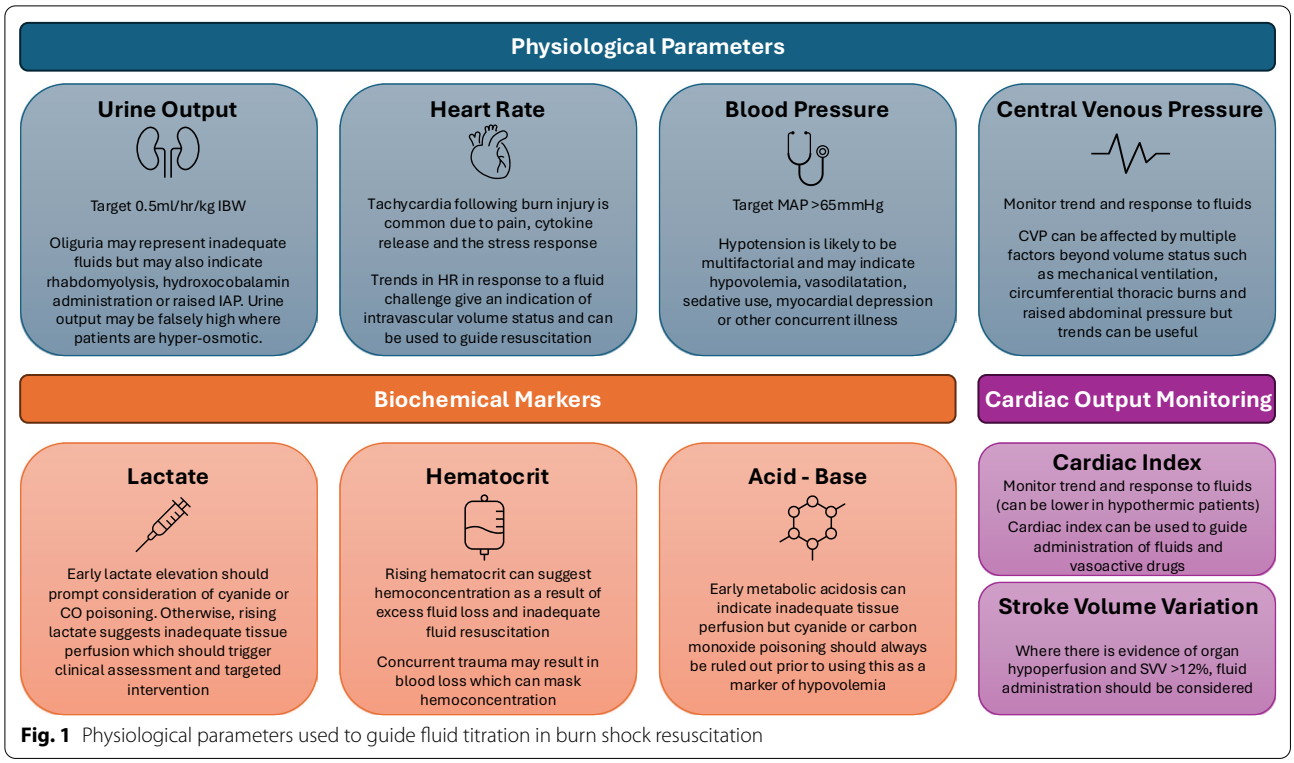
Physiological Parameters
Urine Output
Target 0.5ml/hr/kg IBW
Oliguria may represent inadequate fluids but may also indicate rhabdomyolysis, hydroxocobalamin administration or raised IAP. Urine output may be falsely high where patients are hyper-osmotic.
Heart Rate
Tachycardia following burn injury is common due to pain, cytokine release and the stress response
Trends in HR in response to a fluid challenge give an indication of intravascular volume status and can be used to guide resuscitation
Blood Pressure
Target MAP >65mmHg
Hypotension is likely to be multifactorial and may indicate hypovolemia, vasodilatation, sedative use, myocardial depression or other concurrent illness
Central Venous Pressure
Monitor trend and response to fluids
CVP can be affected by multiple factors beyond volume status such as mechanical ventilation, circumferential thoracic burns and raised abdominal pressure but trends can be useful
Biochemical Markers
Cardiac Output Monitoring
Lactate
Early lactate elevation should prompt consideration of cyanide or CO poisoning. Otherwise, rising lactate suggests inadequate tissue perfusion which should trigger clinical assessment and targeted intervention
Hematocrit
Rising hematocrit can suggest hemoconcentration as a result of excess fluid loss and inadequate fluid resuscitation
Concurrent trauma may result in blood loss which can mask hemoconcentration
Acid - Base
Early metabolic acidosis can indicate inadequate tissue perfusion but cyanide or carbon monoxide poisoning should always be ruled out prior to using this as a marker of hypovolemia
Cardiac Index
Monitor trend and response to fluids (can be lower in hypothermic patients)
Cardiac index can be used to guide administration of fluids and vasoactive drugs
Stroke Volume Variation
Where there is evidence of organ hypoperfusion and SVV >12%, fluid administration should be considered

Fig. 1 Physiological parameters used to guide fluid titration in burn shock resuscitation

and no single parameter should be used in isolation (Fig. 1).

Many protocols are described to guide fluid rate adjustment. Close targeting of urine output with hourly adjustment to infusion volumes based on the previous output is a common theme across protocols. Additional recommendations on hemodynamic monitoring to target specific indices (cardiac index and stroke volume variation) may lead to the overall administration of less fluid but studies are small with limited outcome measures [5]. Most protocols advocate for holistic patient assessment with consideration of all clinical and laboratory variables without the requirement for additional invasive monitoring [5]. Computer-based decision support systems are also available to assist the bedside clinician titrate fluid resuscitation, although meaningful outcome analysis from this approach remains untested [8].

The complex hemodynamic evolution of the patient with burn shock transitions from hypovolemic to distributive shock over the initial 24–48 h and often includes intercurrent cardiac dysfunction [9]. Advances in hemodynamic monitoring technologies, such as pulse contour analysis, ultrasound-based assessments, and bioimpedance devices, may assist with titration of appropriate support. The widespread use of these modalities is limited by cost, training requirements, and, most importantly, lack of definitive evidence supporting their use to improve outcomes [5].

Choice of fluids

The optimal fluid type for burn resuscitation remains a subject of debate. No burn-specific randomized studies are available comparing balanced crystalloids to saline. Given the large quantities of fluid administered in burn patients and the increased risk of metabolic complications attributed to saline (such as hyperchloremic acidosis and acute kidney injury), it seems appropriate to propose balanced crystalloids as first-line solutions. Care should be given when large volumes of Ringers lactate are administered, as hyperlactatemia without acidemia can result, complicating clinical assessment [10]. With plasmalyte administration, calcium levels should be monitored to detect and supplement the onset of hypocalcaemia [11].

The timing and role of albumin administration remain under investigation. Studies indicate that the routine use of albumin reduces the total volume of resuscitation fluids and improves urine output [12]. With the greatest benefits observed in those with more extensive injury, many clinicians now incorporate albumin into their fluid

resuscitation plan in patients with large TBSA or escalating fluid needs [5]. Results of an ongoing randomized controlled trial, the ABRUPT 2 trial (NCT04356859), are eagerly awaited. However, evidence for other colloids, such as fresh frozen plasma, remains insufficient to support routine use beyond concomitant hemorrhagic shock, and current guidelines recommend awaiting RCTs before being incorporated into routine clinical practice [5].

Adjunctive therapies in burn shock

An appropriate dressing should be applied immediately to the burn wound to reduce evaporative fluid losses. In addition, early wound debridement and grafting has recently been promoted for the positive impact on wound healing, risk of sepsis and mortality [13] (NCT02940171). With earlier surgical intervention, fluid shifts might be anticipated; however, the overall impact on systemic inflammation and fluid leak may conversely lead to improvements in burn shock.

Recent investigations have explored pharmacologic adjuncts to reduce fluid requirements and modulate the systemic inflammatory response. Early vasopressors, particularly norepinephrine are increasingly considered in patients with vasodilatory shock, where they may support perfusion while mitigating excessive fluid administration [14]. In addition to addressing the vasoplegia experienced in burn shock, noradrenaline increases venous return and subsequently cardiac output in patients that are adequately resuscitated, and may avoid excess administration of fluids. Potential benefits and harms have yet to be fully studied, and the current evidence base limits any recommendation on the timing of vasopressor initiation. Where there is persistent hypotension following adequate fluid resuscitation, norepinephrine should be considered. In cases of low stroke volume without fluid responsiveness and high CVP, an echocardiography should be performed to evaluate cardiac function and the initiation of an inotrope may be more appropriate.

High-dose vitamin C has gained interest due to its antioxidant and endothelial-stabilizing properties. Preliminary evidence suggests it may reduce fluid requirements and potentially improve survival [15]. However, data in sepsis suggest potential harm; therefore, definitive conclusions in severe burn injury await the results of large-scale randomized trials such as the VICTORY study (NCT04138394).

Ongoing challenges and future directions

Despite advances in protocols and monitoring, several challenges persist. Uncertainty continues regarding the optimal endpoints of fluid resuscitation particularly with regards to the role of technology and novel monitoring tools. The integration of artificial intelligence to guide burn resuscitation is an evolving field that may lead to improvements in avoiding under- or over-resuscitation. The precise role and timing of vasopressors remain ambiguous, and future work to inform practice would be welcomed by the clinical community. Predictive biomarkers such as dipeptidyl-peptidase 3 have shown promise at identifying patients at greater risk of cardiovascular failure [9], but how these markers can be used to inform management remains unclear. Finally, we must recognize that the burden of severe burn injury falls disproportionately on low- and middle-income countries, and strategies for improving management in resource-limited settings will likely lead to the greatest benefit on a global scale.

Conclusion

Fluid resuscitation remains a fundamental intervention in the management of severe burn injury. Evolving understanding has driven a paradigm shift toward individualized, goal-directed strategies, with increasing emphasis on avoiding both under- and over-resuscitation. However, robust evidence remains scarce. Further research is essential to establish best practices, validate emerging therapies and management strategies, and ultimately improve outcomes.

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Declarations

Conflicts of interest
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